

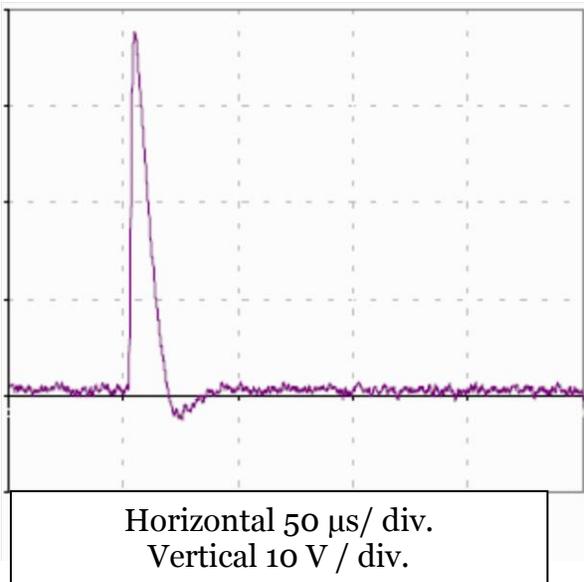
Oscilloscope Applications

Module 1: Oscilloscopes and cow behavioral response

Purpose: Gain experience plotting and analyzing waveforms captured at cow-contact locations.

Learning outcomes: You will learn to classify different types of waveforms and use their phase duration and peak amplitude to plot them on a behavioral response graph.

1. Plot one point for each of the waveforms described below on the behavioral response graph on the next page. Assume each was measured across a 500-ohm shunt resistor.
 - a. A continuous sine-wave with a peak amplitude of 5V and a frequency of 20kHz.
 - b. The transient shown below:



- c. A voltage corresponding to the inrush current of a motor starting. Frequency is 60Hz. The motor takes 10 cycles to accelerate. During starting the voltage is 1.5V RMS at 60Hz. At the end of the 10-cycle acceleration time the voltage drops to 0.2V RMS at 60Hz.
2. Did any of these events exceed their corresponding behavioral response threshold? If so, which one(s)?

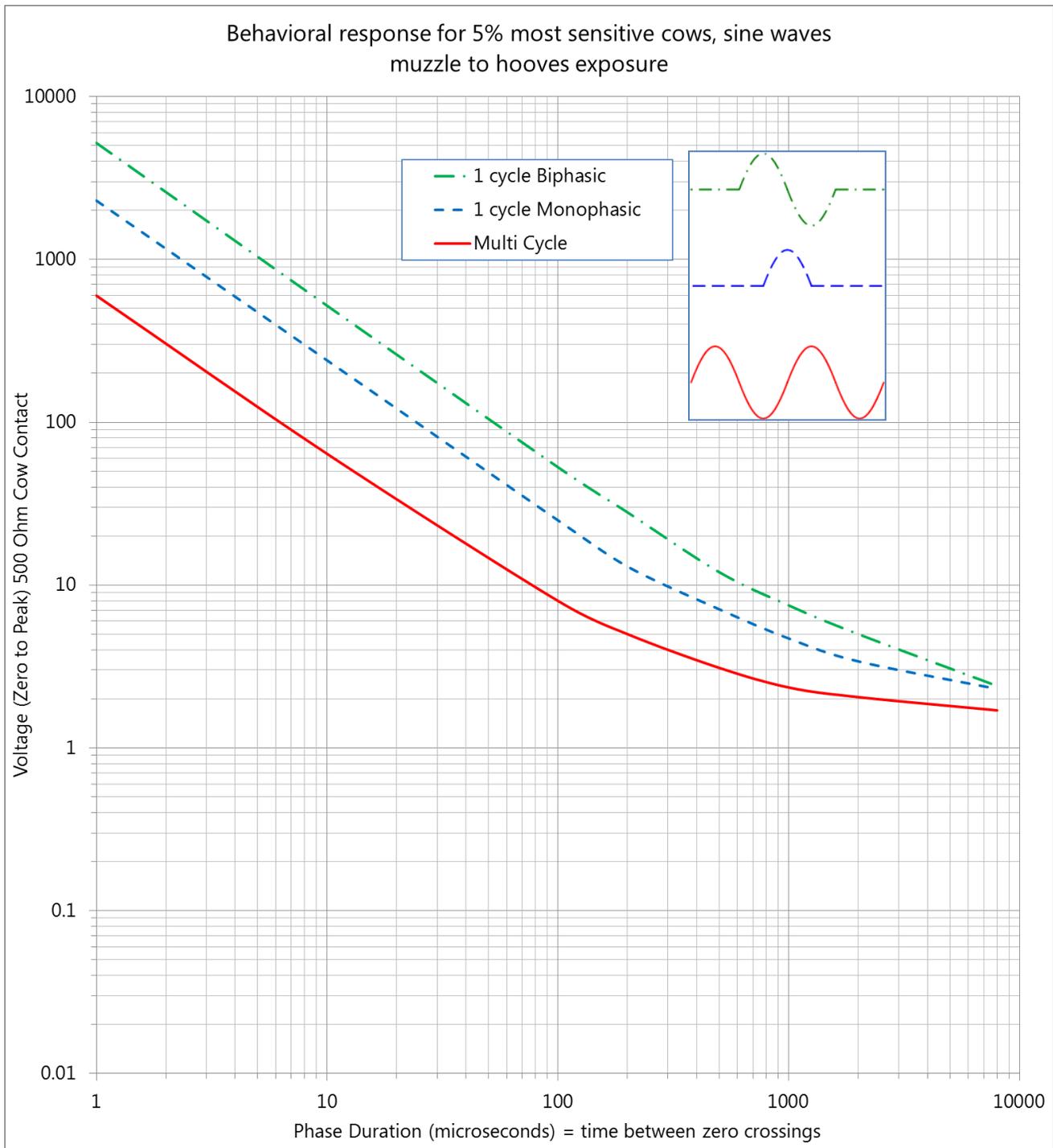
3. What is the zero-to-peak voltage threshold for a monophasic pulse with a phase duration of 40 μ s?

Notes:

Phase duration in microseconds = $1,000,000 / (2 \times \text{frequency in hertz})$

Evaluating steady-state and transient cow-contact voltages:

Cows (and humans) are less sensitive to short duration and higher frequency electrical exposures than they are to longer duration and lower frequency electrical exposures. The strength/duration graph below can be used to determine if a particular steady-state or transient voltage is likely to elicit a response from a sensitive cow.



Adapted from "What do we know about Stray Voltage?" Douglas J. Reinemann, Ph.D.,
University of Wisconsin-Madison, 2009

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Module 2: Preliminary Setup

Objective:

Check/correct scope parameters to start with a “clean” scope.

Learning outcomes:

In this module you will become familiar with setting the scope up for two different types of probes and will check and correct the date and time settings.

1. Set your scope to the factory default settings and clear the oscilloscope’s memory: User > Options > Factory Default (clears memory too) OR hold “user” and turn on (saves memory)

2. Set the correct time (and date if available) in your oscilloscope: User > Options > Date Adjust...

3. Set channel A to voltage, with a 1:1 probe and DC coupling.

4. Does your scope screen indicate the probe attenuation or multiplier and AC or DC coupling for channel A, and if so, how?

5. Set channel B to current, with a 100mV/A probe and AC coupling:

6. Reset the scope to factory defaults again. Did it retain the date and time settings? Did it retain the probe and coupling settings?

Conclusions:

Was your scope set to the correct date and time to begin with? _____
What was the default probe attenuation? _____

AC/DC coupling tradeoffs: In stray voltage investigations we can easily introduce DC voltages into our measurement through the use of different metals in moist environments. However, using AC coupling to eliminate any DC also changes the shape and polarity of the waveform. In general, a good practice is to try both AC and DC coupling after setting up your measurement to see if there is a DC offset in the measurement. For the most accurate waveform representation, use DC coupling.

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Module 3: Getting Signals to Scopes

Objective:

Ensure that the signal gets to your scope with minimal distortion and without picking up excessive noise along the way.

Learning outcomes:

In this module you will have the opportunity to learn how different types of leads affect the integrity of your signal.

1. Connect both ends of a single insulated conductor approximately 10 feet long to one channel of your oscilloscope using a BNC-to-banana binding post. Allow the lead to form a loose, open loop. Observe the waveform on your scope:

2. Disconnect the loop of conductor from your scope and twist the two ends of the conductor around each other, turning them into a twisted pair that is shorted at one end. Reconnect them to your oscilloscope. Is the signal amplitude larger or smaller than in step 1?

3. Replace the “homemade” twisted pair with a shielded twisted pair approximately 5 feet long and shorted at the far end and repeat your observation of the signal. Which signal cable produced the “cleanest” signal at the scope?

Notes:

The voltage leads between a measurement point and your scope, meter, or recorder will probably pass through different electric and magnetic fields which can induce “noise” in the leads. It is important to take steps to minimize this effect. A good first step is to make the leads as short as practical. Using twisted pair leads or shielded twisted pairs helps ensure that the loop area in your voltage leads is very small, and that both leads are exposed to nearly identical electric and magnetic fields. This minimizes the voltage difference that appears between the leads at your instrument due to these external fields. Even if the shield “floats”, it can improve the performance of your signal cable by helping to distribute any electric field evenly around the pair.

Scopes like the Fluke 199 series and the Tektronix TPS and THS series use “isolated” inputs on each channel. This means that the probe reference lead and the probe tip are both isolated from other inputs. Other scopes, like the Tektronix TDS series, do not have isolated inputs. The probe reference leads on all channels are connected together, and to the scope chassis. Care must be taken when using a scope that does not have isolated inputs because the reference leads must all be at the same voltage. For more on this issue, refer to your specific scope’s operating manual.

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Module 4: Capture, measure, and save a continuous waveform

Objective:

Display a continuous waveform on the scope screen and use the scope's built-in automatic measurements to display information about the waveform.

Learning outcomes:

In this module you will have the opportunity to see and practice the following skills:

1. Check the probe multiplier for channel A and adjust it if necessary to match the probes/leads you'll be using.

2. Connect a low-voltage AC source to channel A. Neutral-to-ground voltage at a power outlet or the signal from a function generator is suitable. Does the scope automatically display a stable waveform?

3. If your signal is "noisy" you may need to move the trigger point to get a stable waveform. Experiment with adjusting the trigger point up or down to see if you can make the display stable or unstable. From an unstable waveform, what did you have to do to get a stable waveform?

4. Once a stable waveform is displayed, experiment with time-scale, and voltage-scale adjustments. Your waveform should have at least three full cycles on the screen and should not extend beyond the top or bottom of the screen. Describe the displayed waveform. Is it "noisy"? Are there occasional higher frequency transients displayed?

5. Let the scope measure the peak and phase duration for you. (Fluke)Scope > Reading1 > (on A) > Peak...> PeakMax. Repeat for Reading 2 and select pulse width or frequency (Hz). What is the peak voltage and phase duration of the waveform you captured?

6. Save the captured waveform screen with its readings to your scope's memory, and then recall it from the memory.

Notes: Most scopes will require a few cycles of a waveform in order to accurately calculate an RMS value and measure the frequency. You might experiment with your scope by adjusting the time scale while displaying a frequency and RMS voltage measurement.

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Module 5: Capture a transient and use cursors to measure waveforms

Objective:

Use triggering along with the vertical and horizontal axes adjustments to capture a transient, then use cursors to measure some waveform parameters.

Learning outcomes:

In this module you will have the opportunity to see and practice the following skills:

1. Check your scope's setup (probe attenuation, AC/DC coupling, etc) and adjust as necessary.

2. Connect a signal to channel A of your scope and adjust the trigger point to slightly above any steady-state signal that is present. Set your scope's trigger controls for "single shot" or "trigger and hold". Capture a waveform as you did in Module 4. You may need to adjust your time and voltage scales in order to get a good picture of a transient. Once you have captured a transient, select the horizontal cursors and move them to measure the zero-to-peak voltage of your waveform. What is that voltage?

3. Select the vertical cursors and move them to measure the phase duration of your signal. (Hint, it may be easier to measure the time between a positive and a negative peak if your waveform appears symmetrical):

4. Compare your measurements to those taken by the others in your group who caught the same transient. Do your measurements agree?

5. What was the highest zero-to-peak voltage captured? What was the shortest phase duration captured?

6. Optional: If you have a DMM, connect it to the same source as your scope and set the DMM to min/max mode. How does what the scope records compare to what the DMM "records"?

Capturing transients is often a process of trial and error. The time and voltage scales and triggering point are gradually adjusted to obtain a picture of a waveform that can be measured. Don't worry about missing a transient. Most equipment starts and stops repeatedly, so you will have other opportunities to capture the transient associated with a particular piece of equipment. If a transient is truly a "once-in-a-lifetime" event, then you'll never see it again, and neither will the cows...

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Module 6: Recording with an Oscilloscope

Objective:

Explore your scope's recording capabilities, and possible drawbacks.

Learning outcomes:

In this module you will have the opportunity to experiment with ways to effectively use a scope as a monitor or recorder.

1. Connect your scope to a continuous signal that may include transients, such as neutral-to-ground voltage at a receptacle or a pulse generator such as a “Mr. Pulsar” set to pulse mode. Set the scope to display the zero-to-peak voltage measurement. Set the time axis to 1 or 2s/div. Set the vertical scale to 1 to 5 V/div. so that the steady-state peak-to-peak voltage waveform (a solid band) fits in less than two vertical divisions. What is the approximate steady-state zero-to-peak voltage?

2. Let the scope run for a few minutes and see if you catch a transient, or see how it responds to a transient pulse from a function generator. Describe what you see on the screen:

3. From the scope display, is it possible to measure the phase duration of the transient(s) you captured?

4. Fluke 199 and Tek THS 3000 series scopes include some recording functions. If your scope includes the “trend plot” function, turn it on using the default or “auto” settings and let it run for two to three minutes.

5. After the recording has run for about two or three minutes, stop the recording and select “view all” to view the entire recording. What is the peak voltage recorded?

6. From the trend plot data, is it possible to measure the phase duration of transients that occurred during the recording?

Fluke and Tektronix scopes can capture very fast transients, regardless of the timescale setting. This is called “glitch” or “peak” detect. The Fluke 199 can capture 50ns transients this way. There are 25 screen pixels from one division to the next on the Fluke 199, so each pixel represents 1/25th of the total time per division. If a transient is displayed one pixel wide and the timescale is set to 5s/div., this can make a 50ns transient appear to be 0.2 seconds in duration, or 4 million times longer than the transient actually lasted! A peak in the voltage plot only means that at some point during the plotted interval, the measured voltage reached that peak level. By combining a 5s/div timescale and the 100 screen memory in the Fluke 199's “replay” function, this scope can monitor for 100 minutes and catch both positive and negative peak voltages during this period.

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Module 7: Time of arrival to find transient sources

Objective:

Learn how to use a transient's travel time to help locate its source.

For this module you'll need a square-wave generator or something similar that can produce a pulse with a very steep leading edge. Some transients at a wall outlet may be suitable as well.

Learning outcomes:

In this module you'll look at a single transient with two channels of a scope simultaneously. By comparing the time delay between the arrivals of the transient on each of the channels, you can determine which channel is connected to the source of the transient through a shorter path.

1. Connect a single transient source (square wave generator) to BOTH channels of your oscilloscope, using a short coaxial cable on channel A or 1 and a long coaxial cable on channel B or 2. A difference in length of 50-feet or more is ideal. What is the approximate difference in the length of the two signal leads?

2. Adjust your scope so that you capture and display the leading edge of the transient pulse on both channels with a time scale of about 50ns/div +/- . Do the two waveforms line up vertically, or is one shifted in time compared to the other?

3. What is the time difference between the arrival of the transient at channel A and the arrival of the transient at channel B, in nanoseconds?

4. If you didn't know which channel was "closer" to the transient, could you determine that from these results?

The time-of-arrival method is a powerful tool for locating transient sources. Transient signals will travel away from the source at some fraction of the speed of light through the electrical system. A fast oscilloscope can measure the time it takes the transient to travel between two points. Using leads of equal length and measurement points that are approximately 20-feet or more apart, you can use a scope to determine which point is closer to the source of the transient. In general, the velocity of propagation (VOP) for electrical signals in THHN wire in conduit will be approximately 74 to 84% of the speed of light with a nominal speed of 77%. The VOP for RG-58 or RG-59 coaxial cable is 63% of the speed of light. This method can help you determine if a transient is originating upstream or downstream of a particular point. The test can be repeated at other locations to find the source of a particular transient. Scopes with three or four channels can monitor more than two locations at the same time to speed up the process.

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Module 8: Using a computer with a scope

Objective:

Get an introduction into ways a computer can be used to extend the functionality of your scope.

Learning outcomes:

In this module you will have the opportunity to see how software like “FlukeView” and “Waveform Manager” can be used to record data from your oscilloscope. You will also see how using FlukeView to log readings from a fluke scope can be misleading.

This module will not include a hands-on component because of the time involved in setting up software and scope communications the first time.

FlukeView:

1. Transfer scope screen to computer and save and/or transfer to other applications (email, presentation, word processor, etc.)

This is a valuable function. Scopes have limited memory, so it is useful to be able to retain pictures of scope screens or send them to colleagues via email.

2. Transfer waveform to computer for analysis.

This capability allows you do measure waveform magnitude and phase duration with cursors on your computer rather than on the scope.

3. Display the spectrum of a transferred waveform.

This is particularly useful if you are involved in harmonic analysis.

4. Log readings with FlukeView.

It is important to use this function carefully. Logged readings are for the entire scope screen. Even at its fastest transfer rate, the scope will transfer data to the computer at a rate of about one transfer per second. If the time scale is set for more than one second across the entire screen, then a single microsecond transient could remain on the scope screen for almost a minute, and its peak value would be transferred almost 60 times to the computer. FlukeView will plot this single transient as if it lasted for the entire minute.

Waveform Manager:

Waveform Manager is aftermarket software that works with scopes from a variety of manufacturers. It is useful for analyzing waveforms and also includes the ability to control scope triggering. In this way it can be set to retrieve triggered waveforms from a scope and then reset the trigger. This allows you to capture thousands of transients to your computer's memory automatically, rather than relying on the scope's memory.

1. Transfer waveform to Waveform Manager.

This function is similar to FlukeView's.

2. Use Auto Transfers to transfer triggered waveforms to the computer and adjust scope parameters on the fly until a measurable waveform is captured.

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Module 9: Electrical fingerprints

Objective:

Look at the waveforms associated with switching two or three different devices on and off to reinforce the concept of “characteristic” or “signature” switching transients. This could be considered the device’s “fingerprint”.

Learning outcomes:

Learn how characteristic switching transients can be used to recognize when different devices in a system switch on or off.

1. Set up the scope with a timescale of approximately 10 μ s/div, connected to the neutral-to-ground voltage at a receptacle on an extension cord or power strip. Set the trigger controls so that the scope is not triggering constantly. You may need to set the trigger point a few volts above the normal waveform peak.

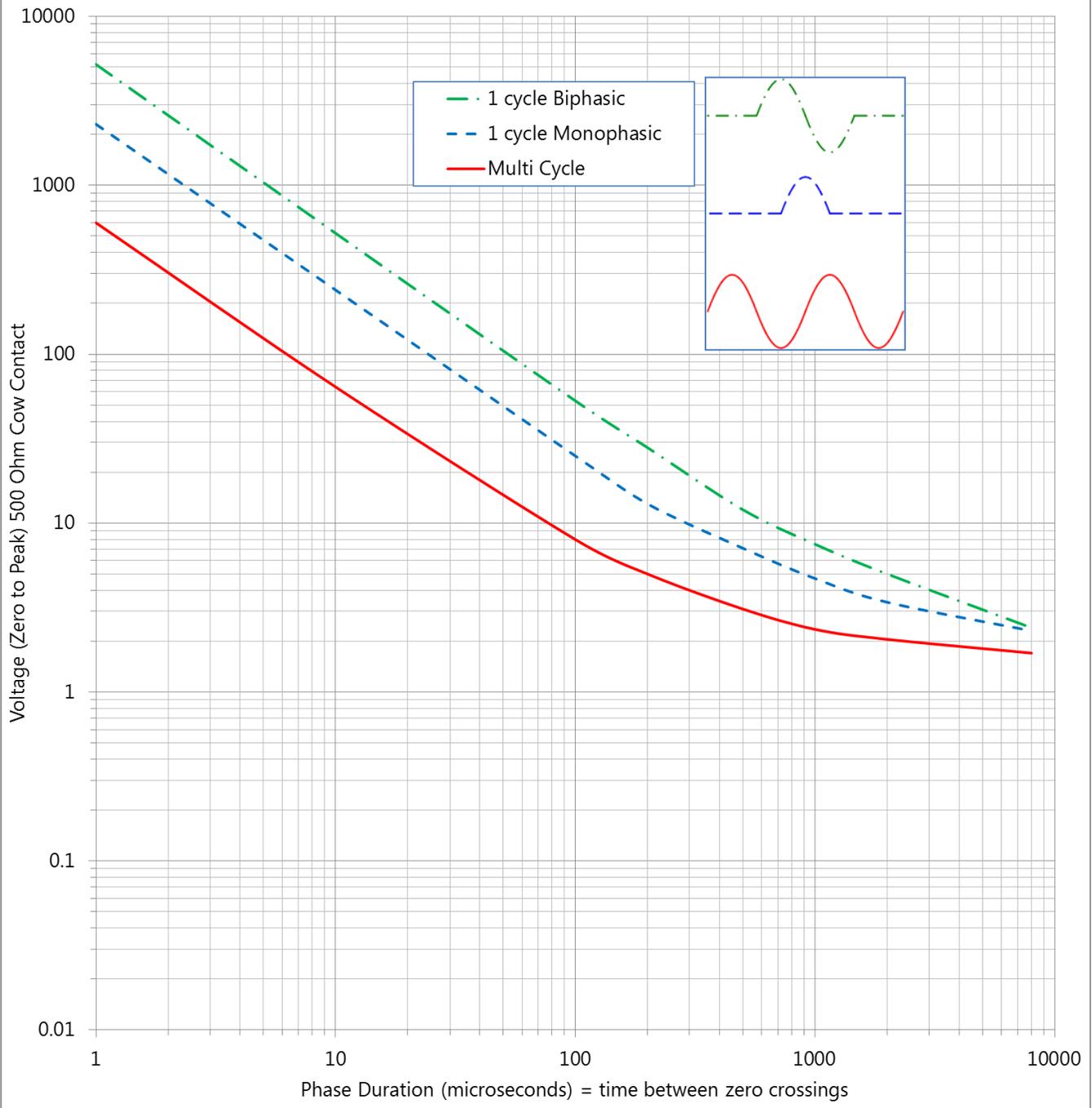
2. Switch a hair dryer, space heater, iron, lamp, fan, or other similar small appliance on and off on the same circuit and observe the captured voltage transients. After a few switching operations, do you start to notice that each device has its own characteristic transients associated with switching on and off?

3. Have someone else in your group switch different devices on and off and capture the switching transient associated with one of the devices they switched. Then see if you can look at the transient waveform they captured and can determine which device switched by switching devices and capturing a very similar waveform yourself. Were you successful in determining which device they captured the transient from?

Notes:

This method isn’t foolproof; there will be some variation in the switching transients for a particular device from one switching operation to the next because of variations in exactly where in the voltage waveform the device is switched and so on. However, this method of identifying transient sources can be used effectively to find the likely source of a repetitive transient.

Behavioral response for 5% most sensitive cows, sine waves
muzzle to hooves exposure



Adapted from "What do we know about Stray Voltage?" Douglas J. Reinemann, Ph.D.,
University of Wisconsin-Madison, 2009